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REPORT DOCUMENTATION PAGE

Form Approved
OMB No 0704-0188

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1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	March 1993	Master's Thesis

4. TITLE AND SUBTITLE

Modeling The Enhanced Integrated Soldier System (TEISS) Using Janus(A)

5. FUNDING NUMBERS

6. AUTHOR(S)

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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

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Monterey, CA 93943-5000

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release, distribution is unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

The purpose of this thesis is to model The Enhanced Integrated Soldier System (TEISS) and analyze the contributions of several factors associated with increasing the lethality and survivability of TEISS. Of interest is the effort to model TEISS, which is still in the conceptual stage, using the Janus(A) high resolution combat model. The database for TEISS was created based solely on the draft Operational Requirements Document (ORD) and the Rationale Annex (Annex A). A 1/8 fractional factorial design was used for this study. Graphical and statistical analyses were performed to consider the impact of increased detection, acquisition, full solution fire control, body protective overgarment, combat load and speed. The results clearly show that the body protective overgarment contributed most to TEISS's ability to survive and the full solution fire control capability is responsible for TEISS's increased lethality in both defensive and offensive operations.

14. SUBJECT TERMS

Janus(A), TEISS, The Enhanced Integrated Soldier System

15. NUMBER OF PAGES

70

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

Approved for public release; distribution is unlimited

Modeling The Enhanced Integrated Soldier System (TEISS) Using Janus(A)

by

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Submitted in partial fulfillment
of the requirements for the degree

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

NAVAL POSTGRADUATE SCHOOL
March 1993

ABSTRACT

The purpose of this thesis is to model The Enhanced Integrated Soldier System (TEISS) and analyze the contributions of several factors associated with increasing the lethality and survivability of TEISS. Of interest is the effort to model TEISS, which is still in the conceptual stage, using the Janus(A) high resolution combat model. The database for TEISS was created based solely on the draft Operational Requirements Document (ORD) and the Rationale Annex (Annex A). A 1/8 fractional factorial design was used for this study. Graphical and statistical analyses were performed to consider the impact of increased detection, acquisition, full solution fire control, body protective overgarment, combat load and speed. The results clearly show that the body protective overgarment contributed most to TEISS's ability to survive and the full solution fire control capability is responsible for TEISS's increased lethality in both defensive and offensive operations.

C.1

TABLE OF CONTENTS

I. INTRODUCTION 1

A. OVERVIEW 1

B. FUTURE THREAT 2

C. BACKGROUND 4

D. ISSUE 5

E. GOALS AND LIMITATIONS 5

F. OUTCOME 7

II. METHODOLOGY MODEL 8

A. JANUS OVERVIEW 8

1. Description of Janus(A) 8
2. Limitations in Modeling TEISS 9
3. Janus(A) - TEISS Database 11

B. TEISS PARAMETERS REPRESENTED IN JANUS(A) . . . 11

1. Ballistic Overgarment Protection 12
2. Soldier Speed 13
3. Full Solution Fire Control 14
4. Improved Detection Capability 14
5. Improved Acquisition 15
6. Combat Load 15
7. Scenarios 16

C. DESCRIPTION OF RED AND BLUE FORCES 16

D. MEASURES OF EFFECTIVENESS 18

III. EXPERIMENTAL DESIGN 19

IV. RESULTS/ANALYSIS 22

A. GENERAL 22

B. COMPUTING MARGINAL AVERAGES AND HALF EFFECTS . 22

C. STATISTICAL ANALYSIS 27

1. Graphical Approach 27

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2. ANOVA/Linear Regression Analysis 29

V. CONCLUSIONS/RECOMMENDATIONS 37

A. CONCLUSIONS 37

B. RECOMMENDATIONS 38

APPENDIX A: FACTORS AND LEVELS 39

APPENDIX B: SAMPLE SINGLE SHOT KILL PROBABILITY (SSKP) TABLES 45

APPENDIX C: SAMPLE P(ACQUISITION) GRAPHS 49

APPENDIX D: AREA OF OPERATIONS USED IN STUDY 53

APPENDIX E: ALIAS TABLE AND CODED DESIGN MATRIX TABLE WITH INTERACTIONS 55

APPENDIX F: RESULTS FROM EACH TRIAL 57

LIST OF REFERENCES 60

INITIAL DISTRIBUTION LIST 62

I. INTRODUCTION

Our warfighting edge is the combined effect of quality people, trained to razor sharpness, outfitted with modern equipment, led by tough, competent leaders, structured into an appropriate mix of forces by type, and employed according to up-to-date doctrine... I am certain the single most important factor is the soldier."

General Sullivan
Army Chief of Staff
July 1991

As a result of the current downsizing of the military forces, the United States Army needs to be more efficient and more effective with fewer resources. This includes our most valuable resource, the soldier. Consequently, military leaders must rely on technology to replace the massive force structure enjoyed in the past. In an attempt to anticipate the design of the future threat and needs of the Army, the United States Army Infantry School (USAIS) is proposing an innovative project: The Enhanced Integrated Soldier System (TEISS). The TEISS soldier will utilize state of the art technology to dramatically improve his lethality, command and control, survivability, mobility, and sustainment.

A. OVERVIEW

The capabilities of the current light infantry soldier are limited by what he can physically carry to the area of operation. Although today's light infantry company can be a lethal force, terrain and visibility can hamper its ability to successfully accomplish the mission. In addition, the

light infantry soldier is vulnerable to the effects of weather, indirect and direct fires, and nuclear, chemical, and biological warfare. Another shortcoming is the lack of real time tactical information to keep soldiers informed of the rapidly changing events on the battlefield. Present doctrine favors a three to one combat ratio if we are to attack and defeat our enemy. However, with the dramatic reductions in military spending and subsequent change in force structure, this desired ratio may prove to be difficult to achieve in the future.

B. FUTURE THREAT

Another consideration which could affect the mission success of the light infantry company is the future threat. With the collapse of the Union of the Soviet Socialist Republics (U.S.S.R.), and the disintegration of the Warsaw Pact, the large scale force on force battle this nation expected to fight perhaps no longer exists. Instead, there remains a high degree of uncertainty which threatens this nation's national interests. Many of the weapons of our once arch enemy can be found in the hands of terrorists and many third world countries. The weapons and technology proliferation ensures a more dangerous future adversary and presents a difficult challenge in the development of U.S. weapons. In addition, regional and political instability exists in countries such as Somalia, Cuba, North Korea, Iran, Iraq, Libya, Venezuela, and the former Yugoslavia.

The military no longer has just one single mission of defending or deterring aggression. Rather, the missions of the Armed Forces are diverse and involve reducing drug trafficking from South America or the Middle East, engaging in humanitarian relief efforts in Bosnia-Herzogovinia, Ethiopia, and Somalia, etc. [Ref. 1] Given the increased complexity of the world situation and the difficulty in defining who the enemy might be, light infantry units need to be prepared to conduct operations against a broad spectrum of threats with little notice. Combat developers and planners must be able to anticipate and wargame the possible consequences of the changing missions today so that tomorrow's soldiers can successfully meet future challenges.

The recent Operation Desert Storm's overwhelming success was the result of some of the most technologically sophisticated munitions, communications, and data gathering devices available today. The pinpoint accuracy of these weapons and the intelligence recorded exploited the available technologies. Had the military leaders, scientists, engineers, and analysts of the past ten or twenty years not had the foresight to develop this capability, the multi-national alliance may not have achieved success so quickly. In addition, the alliance experienced fewer casualties than expected. This too can be attributed to the detailed planning and available "high tech" equipment used during the war. Thus, it is critical

to continue research and development on improving current systems and anticipating the military defense needs of the future.

C. BACKGROUND

The United States Army Infantry School (USAIS) and the United States Army Training and Doctrine Command (TRADOC) in conjunction with the Army Material Command (AMC) have initiated a bold innovative project which will interface the soldier with his equipment into a system which is now known as the "Soldier Integrated Protective Ensemble (SIPE)." The U.S. Army Natick Research, Development, and Engineering Center along with Institute for Defense Analysis (IDA), have been tasked to model SIPE based on current technology. These agencies are using the JANUS(A) high resolution combat model as a tool to help assess the cost/benefit trade-offs. The Soldier Integrated Protective Ensemble is presently in the developmental stage. The SIPE prototype was presented during the Advanced Technology Transition Demonstration (ATTD) which occurred in December 1992 at Fort Benning, Georgia. The successor to the Soldier Integrated Protective Ensemble is The Enhanced Integrated Soldier System (TEISS) which is still in the conceptual stage. Much of the technology needed to create TEISS does not yet exist. Conceptually, TEISS is designed to improve the combat effectiveness of the individual fighting soldier. The combat developers hope that giving the soldier state-of-the-

art technologies will dramatically improve his lethality, survivability, mobility, command and control, and sustainability.

D. ISSUE

There is clearly a need to improve the infantry soldier's capabilities based on the reduction in forces and resources. Combat developers are attempting to determine the impact the conceptualized high-tech future soldier TEISS will have on the battlefield as well as determine how much technology the future soldier really needs to successfully accomplish the mission with minimal losses. Past guidance advocated a force ratio of three to one given that we choose the time and place of battle. "The Enhanced Integrated Soldier System" may allow a smaller infantry force to cover more ground with greater combat effectiveness. Combat planners envision TEISS to be a more lethal force. Thus, fewer soldiers will be needed to accomplish the mission. The analysts and combat developers must be able to measure the potential benefits of the proposed system components up front to assess the cost/benefit trade-offs. This thesis provides some preliminary insight for a system which is still in the conceptual stage of the acquisition process.

E. GOALS AND LIMITATIONS

TEISS is an entirely unique system with many new capabilities which do not yet exist. Modeling the various

attributes of TEISS will help the decision makers understand the impact of these systems on the battlefield. According to the Operational Requirements Document (ORD), [Ref. 2] TEISS will improve on five general areas which affect the soldier's combat effectiveness. These five components are lethality, command and control, survivability, sustainability, and mobility. The operational requirements document for TEISS specifically outlines the desired enhancements affecting each of these five areas. At the present time, there is no combat model that can represent every attribute of TEISS. However, analysts can study some attributes of TEISS using available combat models. The goal of this thesis is to analyze the combat effectiveness of TEISS in terms of lethality and survivability for "The Enhanced Integrated Soldier System" using the Janus(A) High Resolution Combat Model. The parameters selected from the Operational Requirements Document for this thesis are those which significantly increase the soldiers' lethality and survivability:

A) Improved detection - the distance to detect the target increases to at least 100 meters in excess of the maximum effective range of the individual weapon (M-16A2) during night or day. [Ref. 2:pg 4]

B) Full solution fire control system increases the weapons' accuracy by giving the firer the optimum target aim point. [Ref. 2:pg 4]

C) Improved Acquisition increases firer's ability to acquire the target. [Ref. 2:pg 4]

D) Ballistic overgarment protection provides the individual soldier protection from direct fire and indirect fire weapons that are .30 caliber or smaller with a maximum probability of 0.10 of penetration. [Ref. 2:pg 8]

E) Combat load - the total combat load is 25 percent lighter. [Ref. 3:pg 10]

F) Mobility - the soldier's max speed increases from 6 km/hr to 40 km/hr. [Ref. 2:pg 12]

G) Two scenarios: Offense-Hasty Attack; Defense-Hasty Defense.

F. OUTCOME

The results of this research will provide insight as to whether The Enhanced Integrated Soldier System will significantly increase the soldier's lethality and survivability on the battlefield. In addition, the results will consider baseline tradeoff performance between components of the system.

II. METHODOLOGY MODEL

A. JANUS OVERVIEW

1. Description of Janus(A)

Janus(A) is an interactive wargaming combat model which allows for two independent opposing forces (Blue and Red) to engage in battle. In other words, the actions of either side does not depend on those of the opposing force. Janus(A) uses stochastic processes (Monte Carlo) to determine the outcome of an event such as a direct fire hit. Although the principal focus of Janus(A) is to model the combined arms forces and ground maneuver, Janus(A) is also capable of simulating the effects of weather, visibility, chemical environment, minefield employment and other variables.

The Defense Mapping Agency used satellite data to digitize the terrain for a number of areas around the world for use in Janus(A). Each opposing side has their own display which shows a detailed map of the area of operations with their respective players prepared to engage in combat. The terrain features consist of Digital Features Analysis Data (DFAD) and this depicts contour lines, vegetation, roads, rivers, and urban areas. If desired, the user can modify the features of the terrain as well as the size of the area of operation.

The graphic symbols represent systems which may have one or more weapons. For example, one icon on the screen

may represent a single or multiple soldiers on the battlefield along with their respective complement of weapon systems. Each weapon is employed based on its priority of firing. Combat between opposing systems depends on the limitations imposed by the sensor system capability and the physical line of sight between the sensor and target. If the system has line of sight, available ammunition, and if the primary weapon can range the target and is off "hold-fire" status, the system will engage the target. The probability of hit (P_H) and probability of kill given a hit ($P_{K/H}$) tables assigned for each weapon system in the database are used to determine whether an opposing system was hit and/or destroyed. [Ref. 4]

2. Limitations in Modeling TEISS

The concern which arises is whether Janus(A) is the appropriate tool to model the futuristic soldier-TEISS when in fact, the technology to create The Enhanced Integrated Soldier System is not yet available. Since the user is able to easily create new systems or modify existing systems, Janus(A) is a suitable model for analysts to determine the contributions of new and advanced technologies to current systems.

However, Janus(A) does have some drawbacks in modeling the light infantry soldier. For example, Janus(A) will only permit soldier movement if the soldier is in the upright position. Janus(A) does not model other soldier

movement such as the low or high crawl or moving in the crouch position. [Ref. 5] Another disadvantage Janus(A) has in modeling the infantry soldier in combat is the level of the terrain resolution. Currently, the finest terrain resolution available for Janus(A) is 12.5 meter terrain grids. Elevation contour lines can be adjusted down to 10 meters. [Ref. 6]

Although the operational requirements document for TEISS improves the soldier's mobility on the battlefield, Janus(A) is only capable of modeling the physical aspect of reduced combat load and increased speed. As a result, this study considers the impact of soldier speed and combat load as a function of survivability rather than mobility. The mobility characteristic considers human factors effects such as physical stress to the soldier, heat stress, or work rate. Janus(A) is not capable of measuring any of these factors for either side.

Janus(A) was not originally developed to model the light infantry unit at the squad or platoon level. The system was designed to model the motorized and mechanized forces moving across greater distances. Recognizing that the light infantry soldier must walk from one point to another, increased terrain resolution and improved representation of the light infantry soldiers' movements would better reflect a real world scenario. The Janus(A)

high resolution combat model loses some fidelity when modeling the individual soldiers.

3. Janus(A) - TEISS Database

In spite of these shortcomings, Janus(A) is still a powerful resource for modeling several attributes proposed for TEISS. Analysts can study the characteristics of the components that make up The Enhanced Integrated Soldier System to determine the effects they will have on the battlefield. Later testing can integrate and focus on the human factors element.

The database for this research is a training database used at the United States Military Academy. This database does not include any classified material. The training database does include weapon and system characteristics which are available in unclassified Army Field Manuals (FMs) and other documentation which describes the requirements for "The Enhanced Integrated Soldier System". The current light infantry soldier's capabilities reflect the baseline soldier system established in the Janus(A) database.

B. TEISS PARAMETERS REPRESENTED IN JANUS(A)

The Enhanced Integrated Soldier System reflected in Janus(A) improves on several baseline parameters which affect the soldier's survivability and lethality. The increased detection range, improved fire control and target acquisition reflect the soldier's increased lethality

against enemy targets. The improved armor, reduced combat load, and increased speed are associated with TEISS's ability to survive. Although increased mobility is one of the five subsystems of TEISS, this research does not address mobility separately because of the human factor element. As mentioned earlier, Janus(A) can easily model the decreased combat load and increased rate of march, but the system cannot provide data which reflect physical stress levels. Consequently, this study considers these two parameters as a component of survivability.

The following gives a detailed discussion of each of the factors considered as well as the associated variables within the Janus(A) database. Appendix A includes the specific changes in the Janus(A) database for representing these factors. Note that the two levels of the first six parameters are specifically associated with the characteristics of both the baseline soldier and TEISS. The last factor, scenario, consolidates the baseline soldier and TEISS into each scenario level. Thus, there is no distinction between baseline soldier and TEISS in either the hasty offense or hasty defense.

1. Ballistic Overgarment Protection

The purpose of the ballistic protection overgarment is to protect the soldier from direct and indirect fires that are up to .30 caliber in size. Currently, there is no fabric or material available which meets this requirement.

Kevlar is the best substance available today and is presently used in the construction of helmets and flak jackets. But anyone who has worn these items realizes the cumbersome weight hinders the soldier's mobility and combat effectiveness. Although nothing better than kevlar is currently available, Janus(A) can simulate the ballistic overgarment by modifying TEISS's probability of kill given a hit ($P_{K/H}$) tables. Simply stated, the probability that Red kills Blue given that the Red enemy soldier hits Blue decreases significantly. According to the Operational Requirements Document, the probability a Blue is killed given a hit can be no greater than 0.10. Thus, all red $P_{K/H}$ tables affecting TEISS have been set to 0.10 for all postures over all ranges. The total combat load of the baseline soldier can be reduced as well since the TEISS ballistic protection overgarment is proposed to be lighter. Appendix B provides sample single shot kill probability graphs for the twelve postures.

2. Soldier Speed

The average foot march rate for the light infantry unit is approximately six kilometers per hour. According to the requirements document, TEISS can move at a max speed of 40 km/hr using leg enhancers. Although this feature seems a bit futuristic, Janus(A) can easily model this attribute. Realize that soldier speed is dependent on terrain. Thus, traveling across level terrain, TEISS can move at the max

speed of 40 km/hr but crossing a steep hill will decrease the soldier's speed.

3. Full Solution Fire Control

TEISS includes a full solution fire control capability that is integrated with the soldier's primary weapon. The combat developer envisions TEISS having the ability to designate a target using the sensor on the weapon. This will enable TEISS to receive sufficient aim point information to track and engage the enemy. In other words, the full solution fire control capability will enable the weapon system to compute target range, speed, elevation, lead angle, and automatically give the firer the optimum aim point. As a result, TEISS equipped units will require less ammunition. Furthermore, "The Enhanced Integrated Soldier System" will have a greater standoff range from the enemy. [Ref. 2] Janus(A) can model this attribute by increasing the probability of hit (P_H) for all TEISS weapon systems against all enemy target systems. In addition, reducing the basic ammunition load should reflect the need for less ammo as well as reduce the total combat weight.

4. Improved Detection Capability

Relative to the M16A2, improved target detection is required at ranges in excess of 100 meters of the maximum effective range of this weapon. This capability must be effective during all weather conditions and environments

during day and night operations or when other obscurants such as smoke are present. Decreasing TEISS's "Minimum Detection Dimensions" in the Janus(A) database (this is the smallest dimension a sensor must be able to discriminate in order to detect a given system), will make it more difficult for the enemy to locate friendly forces. [Ref. 4:pg 70]

5. Improved Acquisition

Once TEISS detects the target, regardless of visibility, he should be able to acquire and engage the target. Modeling this characteristic requires allowing TEISS to acquire the enemy at greater ranges. In order to improve the acquisition capability, TEISS was equipped with a thermal sensor. Appendix C includes sample graphs of the sensors used in Red versus Blue forces and Blue versus Red Forces.

6. Combat Load

The requirements document for TEISS proposes reducing the soldier's total combat load by 25 percent. Depending on unit policies and mission requirements, the current light infantry soldier may have to carry anywhere from 40-70 pounds of equipment and rations. This extra weight does hamper mobility which in turn may affect the unit's combat effectiveness. The Janus(A) user can easily modify the combat load weight requirements in the "Systems Weights and Volumes" menu of the database. For this research, a combat load weight of sixty pounds was used for

the baseline soldier. Thus, TEISS has a combat load weight of forty-five pounds.

7. Scenarios

The hasty offense and the hasty defense are the two scenarios selected to determine how well TEISS would improve the overall combat effectiveness of a unit. The analyst can easily create these scenarios on the Janus(A) monitors. The scenarios lack some fidelity since one player controls the actions of both opposing forces. Once the side in the defense was positioned, the analyst controlled the movement of the forces in the offense. Thus, there was no player interaction when the enemy was about to defeat the forces in the defense. To limit the variability of the parameters, the systems did not deviate from their preplanned march routes and the game ended with annihilation of one side. As a result, the measures of effectiveness are dependent on the system characteristics rather than the Janus(A) user. The area of operations for both scenarios was the Hoenfehls training area in Germany. Appendix D includes a map of the area of operations used for this study.

C. DESCRIPTION OF RED AND BLUE FORCES

In order to stress the limits of The Enhanced Integrated Soldier System, a standard light infantry squad with an additional light machine-gun team was used against a standard Soviet motorized rifle platoon sized force in the

defense. A five man team was used against the same Soviet force in the offense. A baseline infantry squad which has similar characteristics to today's light infantry unit provides the analyst with a foundation from which to compare the combat effectiveness of TEISS against the same enemy forces.

The baseline and TEISS equipped infantry squads were designated as the Blue forces. The light infantry squad consists of eleven soldiers as shown in Table 1. [Ref. 7:pg 1-1]:

TABLE 1 LIGHT INFANTRY SQUAD

POSITION	WEAPON
SQUAD LEADER	M-16
MACHINE GUNNER	M-60
ASST MACHINE GUNNER	M-16
TEAM LEADER 1	M-16
AUTOMATIC RIFLEMAN	SAW
GRENADIER	M-16 w/M203
RIFLEMAN	M-16
TEAM LEADER 2	M-16
AUTOMATIC RIFLEMAN	SAW
GRENADIER	M-16 w/M203
RIFLEMAN	M-16

The Red force is patterned after the Soviet equipped dismounted motorized rifle platoon. Their forces consist of three squads of seven soldiers as shown in Table 2.

TABLE 2 DISMOUNTED RED INFANTRY SQUAD

POSITION	WEAPON
SQUAD LEADER	AK-74
MACHINE GUNNER	RPK-74
RIFLEMAN/MEDIC	AK-74
GRENADIER	RPG-7V, PM
SENIOR RIFLEMAN	AK-74
RIFLEMAN/ASST GRENADIER	AK-74
RIFLEMAN	AK-74/*SVD

Only one squad in each platoon is equipped with the SVD (sniper rifle). [Ref. 8:pg 1-21]

D. MEASURES OF EFFECTIVENESS

The measures of effectiveness selected reflect the impact survivability and lethality have on combat effectiveness. In other words, by improving today's infantry soldiers' acquisition, detection, fire control, mobility, ballistic protection and combat load, the analyst can assess the affect these parameters have on the unit's overall combat effectiveness. The TEISS project intends to increase the soldier's lethality and survivability substantially. To measure the lethality of TEISS the number of Red Kills/number of Blue Shots Fired was used. The measure of effectiveness for survivability is the number of Blue surviving/number of starting Blue forces.

III. EXPERIMENTAL DESIGN

With the seven parameters described in Chapter I, performing a full factorial design with five replications of each design point to determine the contributions of each parameter would require $2^7 x5 = 640$ separate trials. Since both time and resources are scarce commodities, a one eighth fractional factorial design was developed and run on Minitab (version 8.2). [Ref. 9] This yielded sixteen design points times five replications of each design point for a total of eighty runs. The results of these runs allow the analyst to consider the impact of all primary factors, as well as two-way interactions and one three-way interaction. Since the components of lethality (acquisition, detection, and fire control) seem to be related, this study considered the effect of their interaction. Thus, the Minitab variables were associated with the Janus(A) parameters such that the three-way interaction of acquisition, detection, and fire control could be considered.

The fractional factorial design matrix shown in Table 3 displays the sixteen design points modeled in Janus(A). The factors A through F represent the Baseline soldier and TEISS factors. Factor G, scenario, as discussed in Chapter II, combine the Baseline soldier and TEISS into the two scenarios. If more time and resources were available, it

would have been better to have created a fractional factorial design with eight rather than seven factors. Instead of consolidating the Baseline soldier and TEISS into both scenarios, factor G would have given the value of -1 for the Baseline soldier in the offense and +1 for the Baseline soldier in defense. Similarly, factor H would have assigned the value of -1 for TEISS in the offense and +1 for TEISS in the defense. However, this would have resulted in a design requiring 160 trials with five replications of each of the thirty-two design points.

The capabilities of today's light infantry soldier which are represented by the minuses (-) were used as the baseline for comparison with TEISS which are represented by the pluses (+) in Table 3.

The alias table, which was generated by Minitab (version 8.2), along with the coded fractional factorial design matrix with the interaction columns is included in Appendix E.

TABLE 3 DESIGN MATRIX

Run	A	B	C	D	E	E	G
3	-	-	-	-	-	-	+
7	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-
6	-	-	-	-	-	-	+
6	-	-	-	-	-	-	+
7	-	-	-	-	-	-	+
8	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-
11	-	-	-	-	-	-	+
12	-	-	-	-	-	-	+
13	-	-	-	-	-	-	+
11	-	-	-	-	-	-	+
15	-	+	+	+	-	+	-
16	+	+	+	+	+	+	+

LETTER REPRESENTATIONS

A - Detection
B - Full Solution Fire Control
C - Ballistic Armor
D - Acquisition
E - Combat Load
F - Speed
G - Scenario

IV. RESULTS/ANALYSIS

A. GENERAL

The purpose of the eighty trials performed with Janus(A) is to determine which factors contributed most to TEISS's lethality and survivability. The results will indicate whether there are any major trends which would give a direction for further experimentation. [Ref. 10] The first step in the analysis was to consider any unusual response values and then calculate the response average at each level for each design column. Once completed, the effects $|\Delta|$ and half effects $|\Delta/2|$ can easily be calculated and plotted. This information can then be analyzed using Analysis of Variance or Regression Analysis techniques to determine those factors that are significant. [Ref. 11]

B. COMPUTING MARGINAL AVERAGES AND HALF EFFECTS

The measures of effectiveness (MOEs) for both survivability and lethality were computed using the Janus(A) post-processor in conjunction with General Electric Aerospace's Janus(A) Enhanced Data Analyzer (JEDA). [Ref. 12] The number of Red kills/ number of Blue shots fired was calculated for each of the eighty trials to determine the soldier's lethality. Likewise, the number of Blue forces surviving the battle/the number of starting Blue forces was

computed as a measure for the Blue force's survivability. Since five replications were done for each of the sixteen design points, a mean and standard deviation were computed. Appendix F contains the results of the eighty runs for both lethality and survivability. From the Y_{AVG}'s, the analyst can determine the effects of the primary factors and their interactions by calculating the marginal averages. This calculation is done by summing the response averages of all the (-) and (+) values for each factor and interaction from the design matrix, then taking the absolute value of the difference to get the effects $|\Delta|$. Appendix E, Table 22, contains the coded design matrix with interactions. Minitab generated the first seven columns. The interaction terms are the product of their individual terms. The minuses (-) and pluses (+) represent either the baseline light infantry soldier or TEISS attributes, respectively. Tables 4 and 5 show the response averages for the (-) and (+) values along with the effects $|\Delta|$ and the half effects $|\Delta/2|$ for lethality.

TABLE 4 LETHALITY RESPONSE AVERAGES FOR PRIMARY FACTORS

	A	B	C	D	E	F	G
AVG (-)	.281	.138	.245	.248	.239	.268	.338
AVG (+)	.246	.389	.282	.279	.288	.242	.189
$\|\Delta\|$	.035	.251	.037	.031	.050	.044	.148
$\|\Delta/2\|$	.017	.126	.019	.015	.025	.022	.074

TABLE 5 LETHALITY RESPONSE AVERAGES FOR INTERACTIONS

	AB	AC	AD	AE	AF	AG	BD	ABD
AVG (-)	.275	.248	.246	.236	.280	.277	.236	.260
AVG (+)	.252	.279	.281	.291	.247	.250	.291	.267
| Δ|	.024	.031	.034	.055	.033	.026	.054	.007
| Δ/2|	.012	.015	.017	.028	.016	.013	.027	.003

Tables 6 and 7 depict the computations for the marginal averages and half effects for survivability.

TABLE 6 SURVIVABILITY RESPONSE AVERAGES FOR PRIMARY FACTORS

	A	B	C	D	E	F	G
AVG (-)	.548	.482	.232	.584	.607	.571	.555
AVG (+)	.632	.698	.568	.596	.573	.690	.625
| Δ|	.085	.215	.715	.012	.034	.039	.070
| Δ/2|	.042	.108	.358	.006	.017	.020	.035

TABLE 7 SURVIVABILITY RESPONSE AVERAGES FOR INTERACTIONS

	AB	AC	AD	AE	AF	AG	AD	ABD
AVG (-)	.576	.639	.677	.655	.677	.603	.612	.660
AVG (+)	.605	.541	.568	.526	.703	.577	.568	.521
| Δ|	.029	.098	.175	.129	.225	.025	.044	.139
| Δ/2|	.015	.049	.087	.065	.113	.013	.022	.070

A graphical representation of the marginal effects gives the analyst a better picture of the impact of the various effects on both lethality and survivability. The graphs

shown in Figures 1 and 2, which were created using IBM's statistical software package AGSS [Ref. 13], clearly indicate which variables contribute most to survivability and lethality. Note that the value of each parameter is going from low (Baseline soldier) to high (TEISS).

Figure 1, depicts the average marginals for lethality and are calculated in Tables 4 and 5. This figure indicates that the full solution fire control is the main effect which contributes most towards TEISS's lethality. In addition, it appears as though TEISS was more lethal in the defensive scenario. Looking at the direction of the slope for both speed and detection, it is interesting to note that neither of these factors seem to contribute to TEISS's lethality and in fact they may be a hindrance.

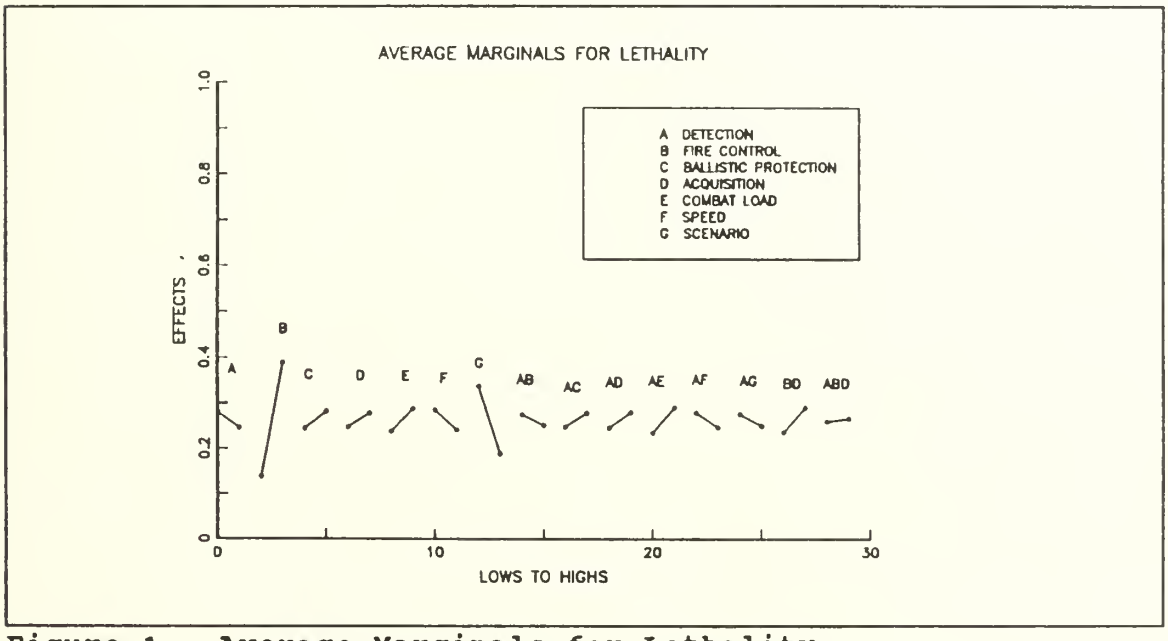

Figure 1. Average Marginals for Lethality

Figure 2 shows the average marginals for survivability and are computed in Tables 6 and 7. This figure clearly indicates that the ballistic protection contributes most to TEISS's ability to survive on the battlefield. There are several other factors, including two-way interactions, which appear to affect survivability as well. Since the two-way interactions are confounded with other two-way factors, it is difficult to assess which interaction is significant without conducting further analysis. Increasing the factorial design from a 1/8 fractional factorial to 1/4 fractional factorial design would allow the analyst to look at all two-way interactions without any other two-way interaction confounding effects.

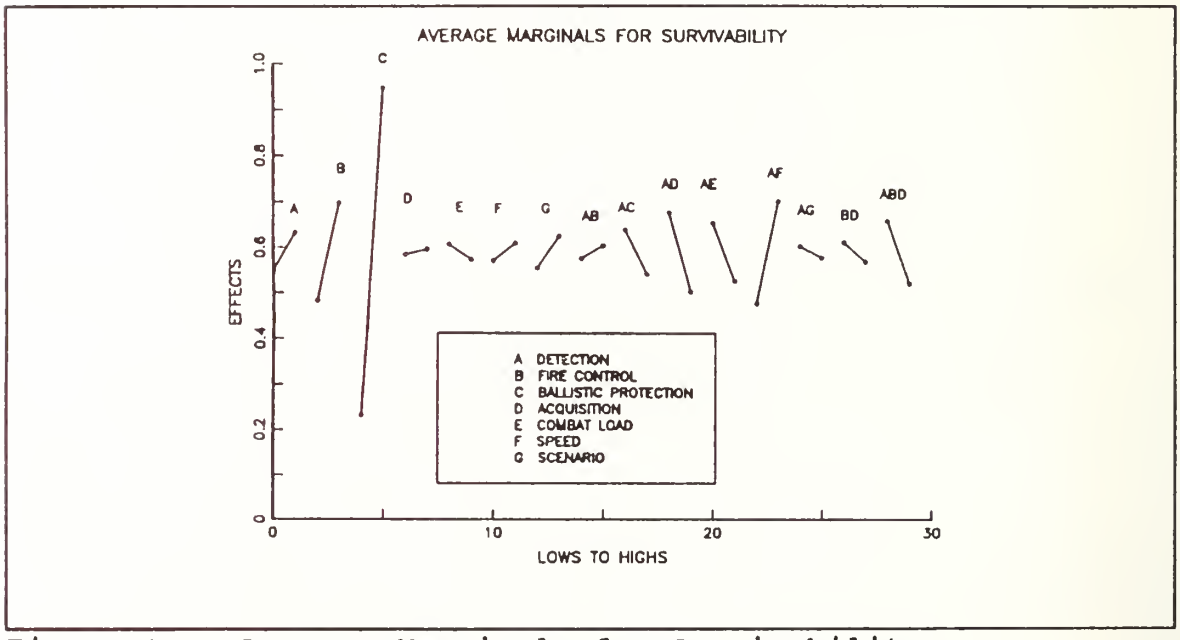

Figure 2. Average Marginals for Survivability

C. STATISTICAL ANALYSIS

1. Graphical Approach

The final step is to determine which factors and interactions are significant. There are three methods available to the analyst to make this determination : graphical, analysis of variance (ANOVA), or regression analysis. The graphical method is based on the size of the half effects which determine the shape of the Pareto chart. Figures 3 and 4 are the Pareto charts of the absolute value of each half effect for lethality and survivability, respectively.

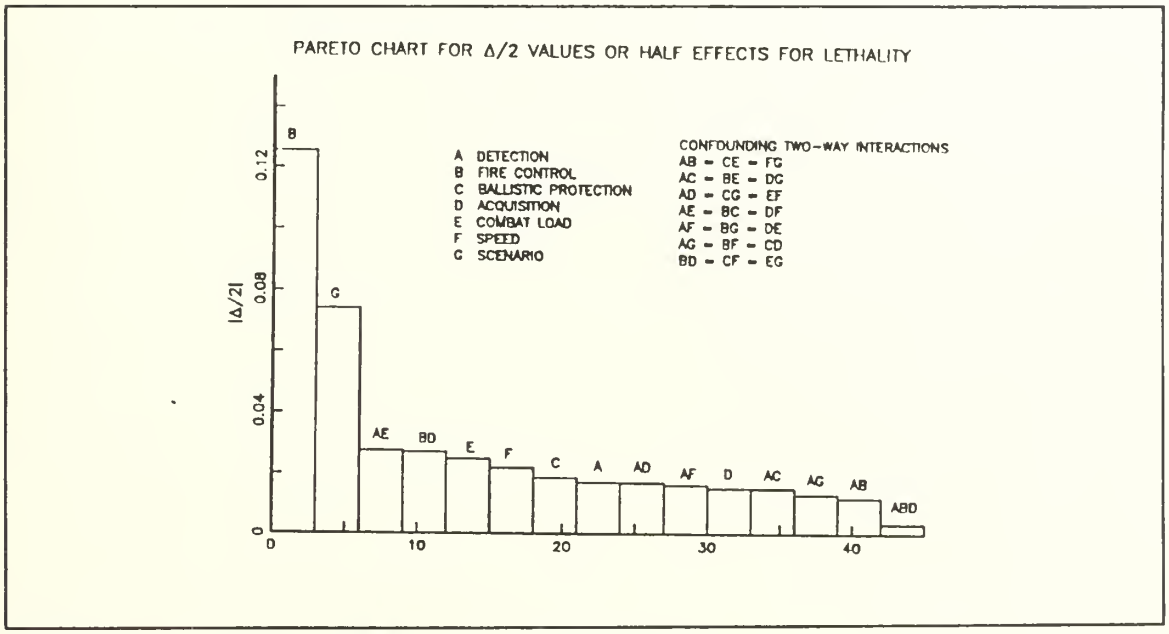

Figure 3 Pareto Chart for Lethality

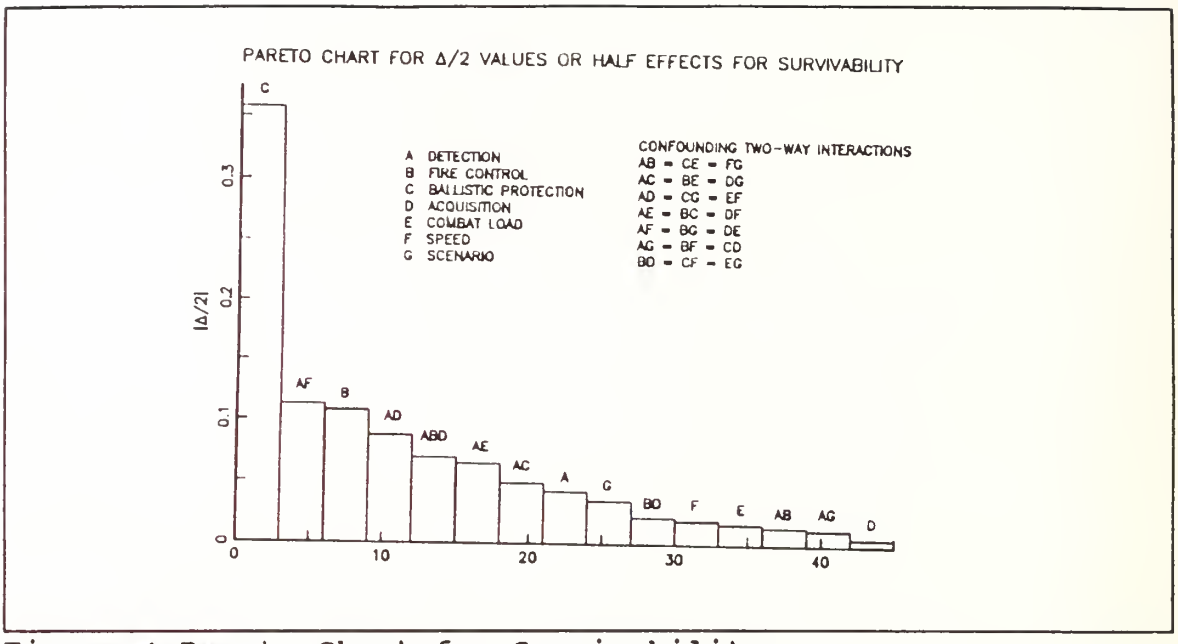

Figure 4 Pareto Chart for Survivability

The two Pareto charts show a distinct separation between the important and negligible effects. For instance, the Pareto chart for lethality suggests that the full solution fire control and possibly the type of scenario may be two important factors. Likewise, the Pareto chart for survivability clearly indicates that the body protective overgarment contributes greatly to TEISS's ability to survive. There are other two-way interactions along with the fire control (B) factor which may be significant. Performing additional statistical analysis will help determine the significance of these factors in question. As noted earlier, since the two-way interactions are confounded with other two-interactions, it is difficult to assess which interaction is significant without increasing the size of the fractional factorial design.

2. ANOVA/Linear Regression Analysis

The statistical software package Minitab version 8.2 is able to analyze a fractional factorial design. Minitab can compute the analysis of variance table as well as fit the model using a linear regression approach. Minitab can also compute the effects of each term.

The Minitab lethality results for estimated effects and regression coefficients are shown in Table 8.

TABLE 8 MINITAB RESULTS FOR LETHALITY

TERM	EFFECT	COEF	STD COEF	t-Value	P
Constant		0.26344	0.008438	31.22	0.000
DET	-0.03459	-0.01729	0.008438	-2.05	0.045
FC	0.25093	0.12547	0.008438	14.87	0.000
BP	0.03738	0.01869	0.008438	2.21	0.033
ACQ	0.01060	0.01060	0.008438	1.82	0.073
WT	0.04967	0.02483	0.008438	2.94	0.005
SPD	-0.04395	-0.02198	0.008438	-2.60	0.011
BP	-0.14824	-0.07412	0.008438	-8.78	0.000
DET*FC	-0.02198	-0.01194	0.008438	-1.42	0.160
DET*BP	0.03050	0.01525	0.008438	1.81	0.075
DET*ACQ	0.03424	0.01712	0.008438	2.03	0.047
DET*WT	0.05507	0.02753	0.008438	3.26	0.002
DET*SPD	-0.03276	-0.01638	0.008438	-1.94	0.057
DET*BP	-0.02637	-0.01318	0.008438	-1.56	0.123
FC*ACQ	0.05409	0.02705	0.008438	3.21	0.002
DET*FC*ACQ	0.00676	0.00338	0.008438	0.40	0.690

The t-values and P values from Table 8 also support the earlier findings. The fire control and scenario factors are significant and contribute to the lethality of TEISS.

The ANOVA table created by Minitab aggregates the main effects and 2-way interactions and does not provide as much detailed information regarding the contributions of each factor. Table 9 depicts the Minitab lethality results for the analysis of variance (ANOVA) table.

TABLE 9 ANOVA TABLE FOR LETHALITY

SOURCE	DF	SEQ SS	ADJ SS	ADJ MS	F	P
MAIN EFFECTS	7	1.85765	1.85765	0.265378	46.59	0.000
2-WAY INTERACTIONS	7	0.20799	0.20799	0.029713	5.22	0.000
3-WAY INTERACTIONS	7	0.00091	0.00091	0.000914	0.16	0.690
RESIDUAL ERROR	64	0.36455	0.36455	0.005696		
PURE ERROR	64	0.36455	0.36455	0.005696		
TOTAL	79	2.43110				

The Minitab survivability results for estimated effects and regression coefficients are reflected in Table 10.

TABLE 10 MINITAB RESULTS FOR SURVIVABILITY

TERM	EFFECT	COEF	STD COEF	t-VALUE	P
CONSTANT		0.59000	0.01306	45.18	0.000
DET	0.08455	0.04227	0.01306	3.24	0.000
FC	0.21545	0.10773	0.01306	8.25	0.000
BP	0.71546	0.35773	0.01306	27.40	0.000
ACQ	0.01182	0.00591	0.01306	0.45	0.652
WT	-0.03364	-0.01682	0.01306	-1.29	0.000
SPD	0.03909	0.01955	0.01306	1.50	0.139
SC	0.07001	0.03500	0.01306	2.68	0.009
DEC*FC	0.02909	0.01455	0.01306	1.11	0.269
DET*BP	-0.09818	-0.04909	0.01306	-3.76	0.000
DET*ACQ	-0.17454	-0.08727	0.01306	-6.68	0.000
DET*WT	-0.12910	-0.06455	0.01306	-4.94	0.000
DET*SPD	0.22545	0.11273	0.01306	8.63	0.052
DET*SC	-0.02545	-0.01273	0.01306	-0.97	0.333
DET*ACQ	-0.04364	-0.02182	0.01306	-1.67	0.100
DET*FC*ACQ	-0.13910	-0.06955	0.01306	-5.33	0.000

Table 11 is the ANOVA table for survivability.

TABLE 11 ANOVA TABLE FOR SURVIVABILITY

SOURCE	DF	SEQ SS	ADJ SS	ADJ MS	F	P
Main Effects	7	11.4630	11.4630	1.63757	120.05	0.000
2-Way Interactions	7	2.22000	2.2200	0.31714	23.25	0.000
3-Way Interactions	7	0.3870	0.3870	0.38696	28.37	0.000
Residual Error	64	0.8730	0.8730	0.01364		
Pure Error	64	0.8730	0.8730	0.01364		
Total	79	14.9429				

It is interesting to note that the Minitab effects computations are exactly the same as those calculated earlier. In addition the regression coefficients shown in the Minitab output are identical to the half effects determined earlier for the Pareto plots. Thus, the Minitab results are consistent with the previous graphical analysis.

From the results, the analyst can develop a prediction equation which includes those factors and interactions which describe the response. The general form of the prediction equation is:

$$\hat{y} = \bar{y} + \left(\frac{\Delta_A}{2}\right)A + \left(\frac{\Delta_B}{2}\right)B + \left(\frac{\Delta_{AB}}{2}\right)AB + \ldots + \left(\frac{\Delta_{ABD}}{2}\right)ABD$$

$\hat{y}$ = predicted response

$\bar{y}$ = average of all response values from the experiment data

$\Delta_A/2$ = half effect for factor A [ref 11]

The $\bar{y}$ value for lethality is the grand mean of the sixteen y_{AVG}'s calculated in Table 23 of Appendix D. The coefficients for each of the factors are the calculated half effects $|\Delta/2|$ from Tables 4 and 5 or the values of the regression coefficients found in Table 8.

The factors used in the prediction equation for both lethality and survivability were determined based on the significance of each factor and interaction using an $\alpha = 0.05$. Thus, evaluating the P values from Tables 8 and 10 for lethality and survivability, respectively, provides the factors needed for each of the prediction equations.

The prediction equation for lethality is as follows:

$$\hat{Y}_{LETHALITY} = .2634 + (.0173)A + (.1255)B + (.0187)C + (.0248)E + (.0220)F + (.0741)G + (.0171)AD + (.0275)AE + (.0271)BD$$

The next step is to select the best settings for each of the significant factors included in the prediction equation and determine which setting would maximize the soldier's lethality. Note that each of the included variables will either take on a value of +1 or -1 depending on whether the slopes for the marginal effects (Figures 1 and 2) for each factor was high at the +1 TEISS setting or high at -1 Baseline soldier setting. Factor G, scenario, is an exception to this rule. The low level (-1) of factor G is hasty defense and the high level (+1) is attack for both TEISS and the Baseline soldier. Future designs could consider these as two separate factors. However, because of time and resource limitations for this study, only one scenario factor was included. The levels of each factor can be determined from examining the slopes of the effects in Figure 1. Looking at the slopes of these factors on the marginal average plots, the highest peak occurs when fire control (B), ballistic protection (C), combat load (E), and the two-way interactions detection-acquisition (AD), detection-combat load (AE), and fire control-acquisition (BD) are set for the TEISS value of +1. On the other hand, the slopes for detection (A) and speed (F) have their highest peaks when set for the baseline soldier value of -1. The slope for scenario (G) peaks when set for the hasty defense value of -1. Thus the predicted maximum lethality is:

$$\hat{y}_{LETHALITY} = .2634 + (.0173)A_{-} + (.1255)B_{+} + (.0187)C_{+} + (.0248)E_{+} + (.0220)F + (.0741)G_{-} + (.0171)AD_{+} + (.0275)AE_{+} + (.0271)BD_{+}$$

$$\hat{y}_{LETHALITY} = 0.3907$$

Based on the P values from Table 10, the predicted response for survivability is:

$$\hat{y}_{SURVIVABILITY} = .5900 + (.0423)A + (.1077)B + (.3577)C + (.0491)AC + (.0873)AD + (.0646)AE + (.1127)AF + (.0696)ABD$$

Similar to the predicted response for lethality, the $\bar{y}$ is the grand mean of the sixteen y_{AVG}'s for survivability found in Table 22. The coefficients for the factors are the half effects $|\Delta/2|$ found in Tables 6 and 7 or the values of the regression coefficients found in Table 10. Like the predicted response for lethality, the objective is to maximize the soldier's ability to survive on the battlefield. Therefore, the values for detection (A), fire control (B), ballistic protection (C), and detection-speed (AF) have their highest peaks at the +1 value. In contrast, the slopes for the two way interactions detection-ballistic protection (AC), detection-acquisition (AD), detection-combat load (AE) and the three-way interaction detection-fire control-acquisition (ABD) have their highest peaks when set to -1. Thus, the predicted value for survivability is as follows:

$$\hat{y}_{SURVIVABILITY} = .5900 + (.0423)A_{+} + (.1077)B_{+} + (.3577)C_{+} + (.0491)AC_{-} + (.0873)AD_{-} + (.0646)AE_{-} + (.1127)AF_{+} + (.0696)ABD_{-}$$

$$\hat{y}_{SURVIVABILITY} = 0.9398$$

Although the plot averages from the marginal average plots would have resulted in the same conclusion as the above prediction equation, the graphical approach does not provide a precise prediction value. [Ref. 11]

V. CONCLUSIONS/RECOMMENDATIONS

A. CONCLUSIONS

The outcome of this study employed both graphical and statistical methods of analysis. Using the characteristics of today's light infantry soldier as a comparison to The Enhanced Integrated Soldier System, the results determined which factors contributed most to the soldier's increased survivability and lethality in basic offensive and defensive type missions. Since TEISS is still in the conceptual stage of development, there is no real means of confirming the validity of the findings from this study. In addition, the Operational Requirements Document and Mission Need Statement do not provide specific details on the parameters selected for this study. Thus, modeled in Janus(A), this future soldier does appear invincible compared to the baseline soldier. Since Janus(A) is a physics based model, the outcome is only as good as the database.

Although not analyzed, the initial starting forces of Blue in the offense was almost 2:1 and in the defense, the starting force was about 4:1. In most cases when the TEISS body protective armor parameter was in play, TEISS would often win the battle.

Even though the concept of TEISS seems futuristic today, the results of the simulations can provide combat planners with an idea of the value such a system can provide on the battlefield.

B. RECOMMENDATIONS

Subsequent studies should synchronize the simulation and modeling efforts as major revisions to the Operational Requirements Document for The Enhanced Integrated Soldier System are accomplished. As the specifications for TEISS become more concrete, a more robust model may be needed in the future. Further study considering just the survivability and lethality aspect could be done involving more complex missions, different type terrain, as well as different type units. Combat developers envision TEISS being employed for special forces, airborne, air assault, and mechanized infantry units. The areas for further study are vast and include using other models which account for command and control, sustainability, and mobility. A more important consideration is the human factors aspect of employing this equipment as an integrated system.

APPENDIX A: FACTORS AND LEVELS

The following reflects the changes made in the Janus (A) database regarding the Baseline light infantry soldier and the futuristic TEISS. The pluses (+) represent the attributes for TEISS and minuses (-) represent the characteristics for the Baseline soldier. The database is an unclassified training database that was used at the United States Military Academy. The Baseline soldier attributes are derived from unclassified manuals and the data for TEISS is taken from the Operational Requirements Document. [Ref 2] Reference 4 gives the detailed explanation of each Janus(A) menu and their respective fields.

A. DETECTION [Janus Menu Command: SY-CC-DD]

The Minimum Detection Dimensions (meters)- establishes the smallest dimension a sensor must be able to detect in order to acquire a target.

The Thermal Contrast Class (exposed/defilade) - equals the difference in degrees centigrade between a system's temperature and its background. The higher the number the greater the contrast.

Sensors - Points to a specific sensor in the Janus(A) database.

TABLE 12 MINIMUM DETECTION DIMENSIONS

	Min Detect (meters)	Thermal Exposed	Thermal Defilade	Primary Sensor	Alt Sensor
+ TEISS	0.20	4	5	4	2
- BASELINE	1.20	8	9	1	2
RED FORCES	1.2	8	9	1	2

B. FULL SOLUTION FIRE CONTROL [Janus Menu Command: SY-WW]

NOTE: P_H for Blue hits Red increases

The P_H points to a specific probability of hit table in the Janus(A) database.

TABLE 13 ASSOCIATED P_H TABLES

+ TEISS	P_H TABLE	
	263	BLUE WEAPON 72 (5.56T-RFL)
	263	BLUE WEAPON 75 (M203T40MM)
	264	BLUE WEAPON 73 (5.56T-SAW)
	264	BLUE WEAPON 74 (7.62T-MG)
- BASELINE	P_H TABLE	
	164	BLUE WEAPON 51 (5.56 RFL)
	164	BLUE WEAPON 80 (M203 40MM)
	165	BLUE WEAPON 52 (5.56 SAW)
	211	BLUE WEAPON 53 (7.62 MG)

C. BALLISTIC PROTECTION

Modify $P_{K/H}$ tables (red kills blue decreases). Note that the P_H tables for red hits blue remains the same. The $P_{K/H}$ Table column points to a particular table in the

Janus(A) database. Appendix B contains sample single shot kill probabilities (SSKP) tables.

TABLE 14 ASSOCIATED $P_{K/H}$ TABLES FOR RED VS BLUE

Red System #/Name	(-) $P_{K/H}$ Table	(+) $P_{K/H}$ Table
51/5.45 RFL	164	150
52/7.62 MG	211	151
69/5.45 MG(SVD)	165	155
74/9mm PM	170	156

D. ACQUISITION

1. Modify visibility under the general characteristic [Janus Menu Command: SY-CC-GG]. The Visibility field establishes the maximum range at which a system can detect enemy targets.

TABLE 15 VISIBILITY IN KILOMETERS

	Visibility (Km)
+ TEISS	4.0
- BASELINE	2.0

2. Modify Weapon Lay time [Janus Menu Command: WP-CC]. The lay time is the average time in seconds to lay the weapon for direction.

TABLE 16 WEAPON LAY TIMES IN SECONDS

	Weapon Name	Lay Time
+ **TEISS**	T-RFL	2
	T-SAW	2
	T-LMG	3
	T-M203	2
- **BASELINE**	RFLMAN	4
	SAW	4
	LMG	4
	M203	4

E. COMBAT LOAD [Janus Menu Command: SY-CC-VV]

The additional weight in pounds reflects the carrying capacity of the soldier. The additional volume capacity in cubic feet establishes the soldier's carrying capacity.

TABLE 17 COMBAT LOAD TABLE

	Additional Weight (lbs)	Capacity (CuFt)
+ **TEISS**	45	3
- **BASELINE**	60	4

F. MOBILITY

1. Change the max road speed on both the JSCREEN III and Janus Menu Command: SY-CC-GG.

TABLE 18 MAXIMUM SOLDIER SPEED

+ TEISS	40 Km/Hr
- BASELINE	6 Km/Hr

2. TEISS will require a power source to maintain speed of 40Km/Hr. Model this attribute using the fuel menu [Janus Menu Command: SY-CC-PP]. [Ref 14]

The type fuel field indicates the type of fuel the system uses. The tank size refers to the capacity of the system's fuel tank. The consumption rate reflects the amount of fuel used while the system is stationary or moving.

TABLE 19 TEISS FUEL REQUIREMENTS

	Fuel Type	Tank Size	Stationary Consumption	Moving Consumption
+ TEISS	2	36	.5	6.0
- BASELINE	-	-	-	-

G. SCENARIO

Appendix D contains a map of the area of operations.

TABLE 20 SCENARIO LEVELS

+ Offensive
- Defensive

APPENDIX B:

SAMPLE SINGLE SHOT KILL PROBABILITY (SSKP) TABLES

Figures 5, 6, and 7 are sample single shot kill probabibilities for the twelve types of target postures used by Janus(A). The single shot kill probabilities are the product of the $P_{K/H}$ * P_H. These probabilities are based on the maximum effective range of the weapon. The four letters at the top of each graph represent the posture of firer vs target. The following gives a quick summary of their meanings:

First Letter: Specifies the motion of the firer
(S) Stationary (M) Moving

Second Letter: Specifies the motion of the target
(S) Stationary (M) Moving

Third Letter: Specifies the target's exposure
(E) Fully Exposed (D) Defilade

Fourth Letter: Specifies the aspect of the target with respect to the firer.
(F) Flank (H) Head

Figure 5 shows the SSKP graphs for a Baseline rifleman firing at the Red rifleman. Although not included, the graphs are the same for the Red rifleman firing at the Baseline rifleman. Figure 6 is the SSKP graphs for TEISS rifleman firing at the Red rifleman. Figure 7 shows the SSKP graphs for the Red rifleman firing at TEISS rifleman.

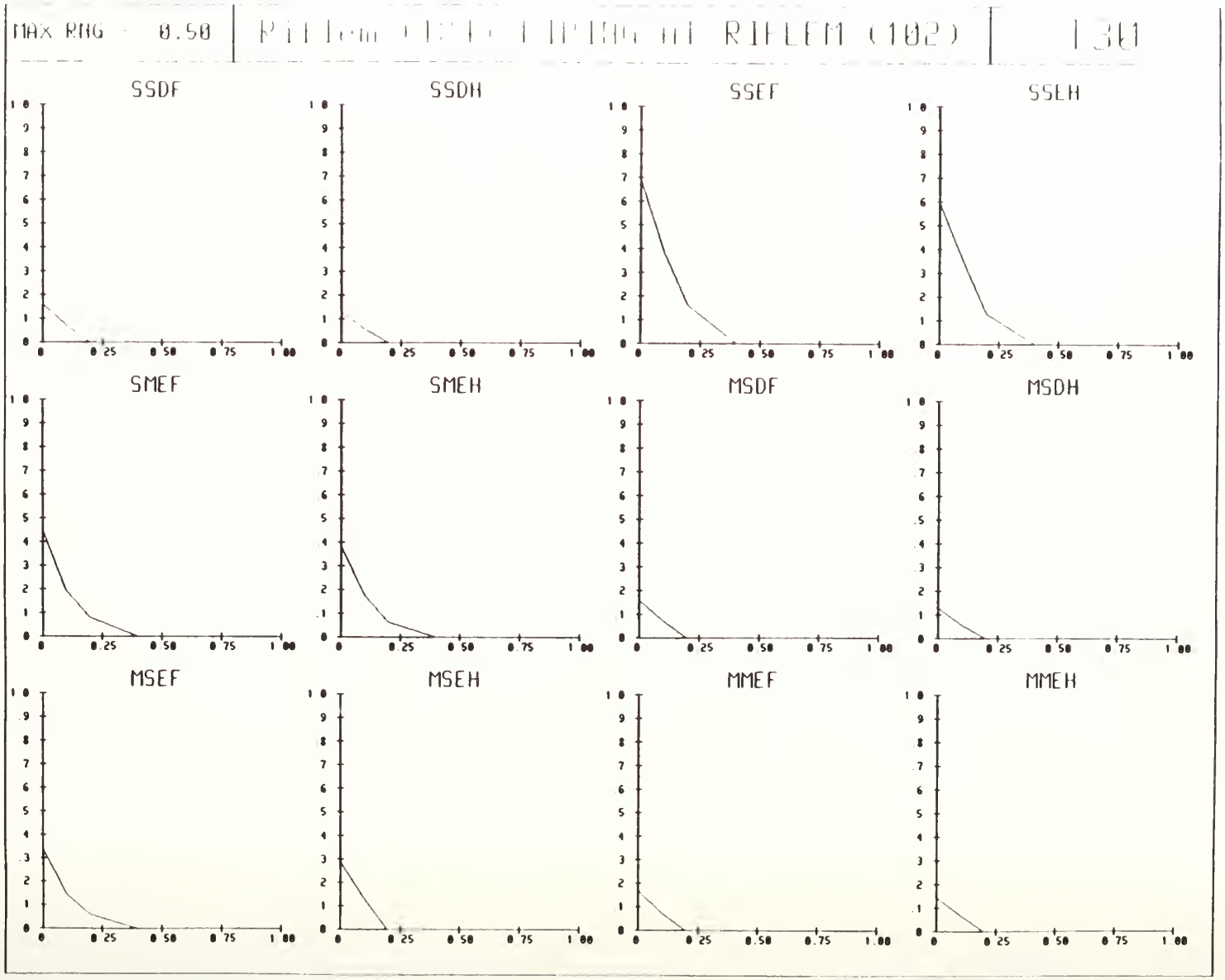

Figure 5. SSKP for Blue Baseline Rifleman (184) firing at Red Rifleman (102)

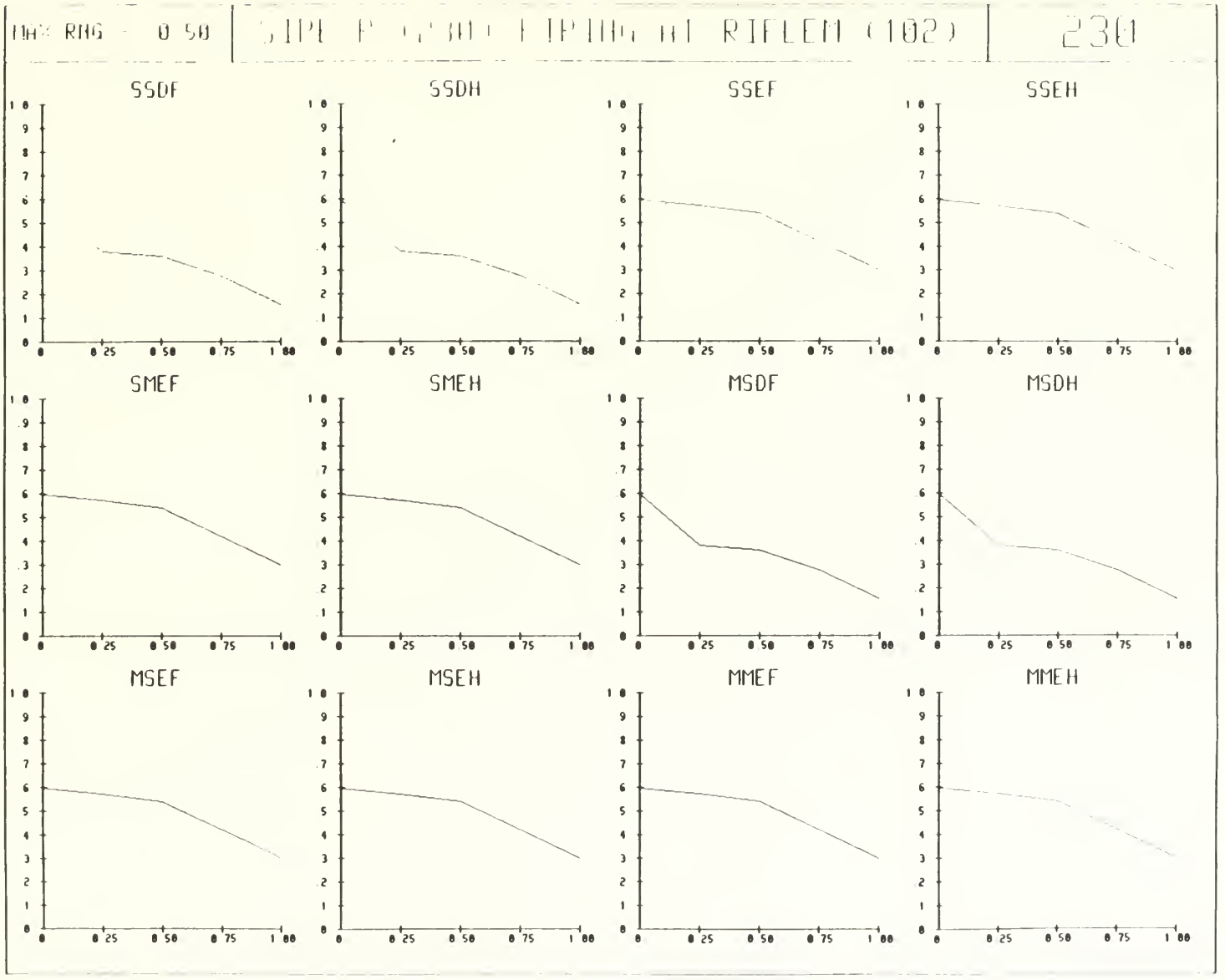

Figure 6. SSKP for Blue TEISS Rifleman (230) firing at Red Rifleman (102)

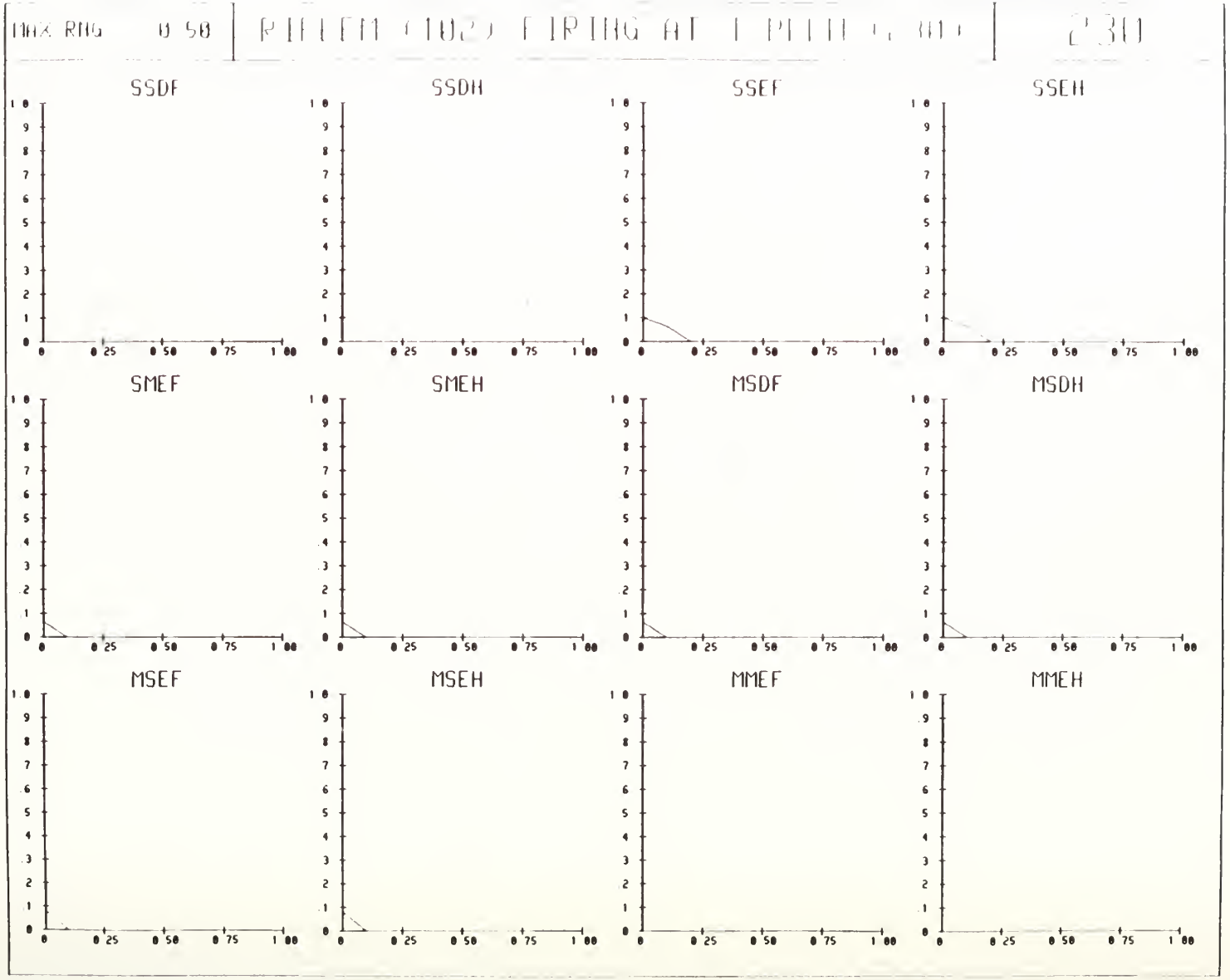

Figure 7. SSKP for Red Rifleman (102) Firing at Blue TEISS Rifleman (230)

APPENDIX C: SAMPLE P(Acquisition) GRAPHS

Figures 8, 9, and 10 reflect the probablility of acquiring a target. The first graph depicts the Blue baseline rifleman (184), with a standard M-16 weapon targeting the Red Rifleman (102). The second graph shows the TEISS rifleman (230) equipped with an integrated M-16 targeting the Red Rifleman (102). The major difference between graph one and two are the ranges in which the respective Blue force can acquire its target. The final graph shows the probability that the Red rifleman (102) will acquire the TEISS rifleman. The reader should note that the probability that the Red Rifleman acquires the baseline Blue rifleman is the same as the baseline Blue rifleman acquiring a Red rifleman.

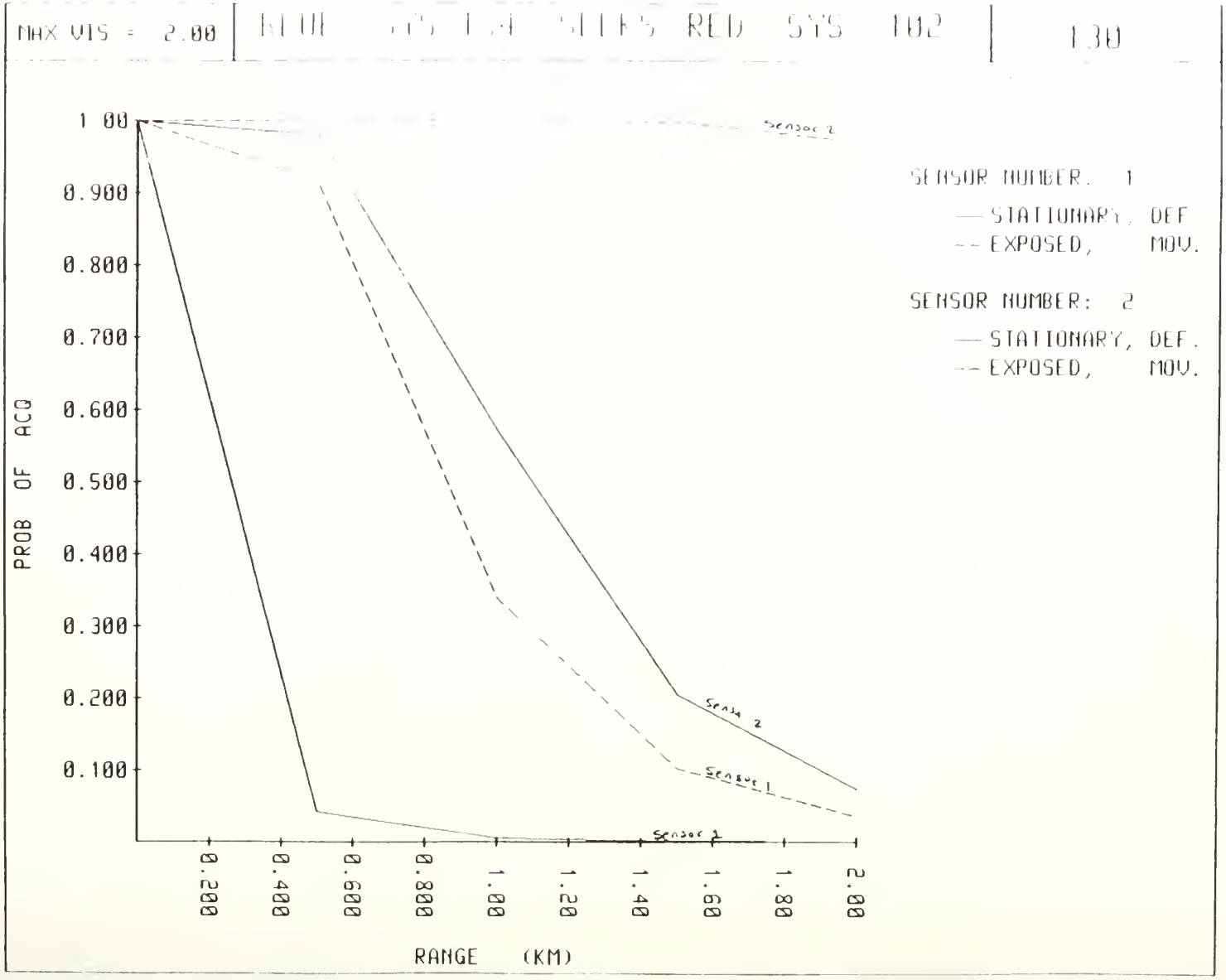

Figure 8. Blue Rifleman (184) seeks Red Rifleman (102)

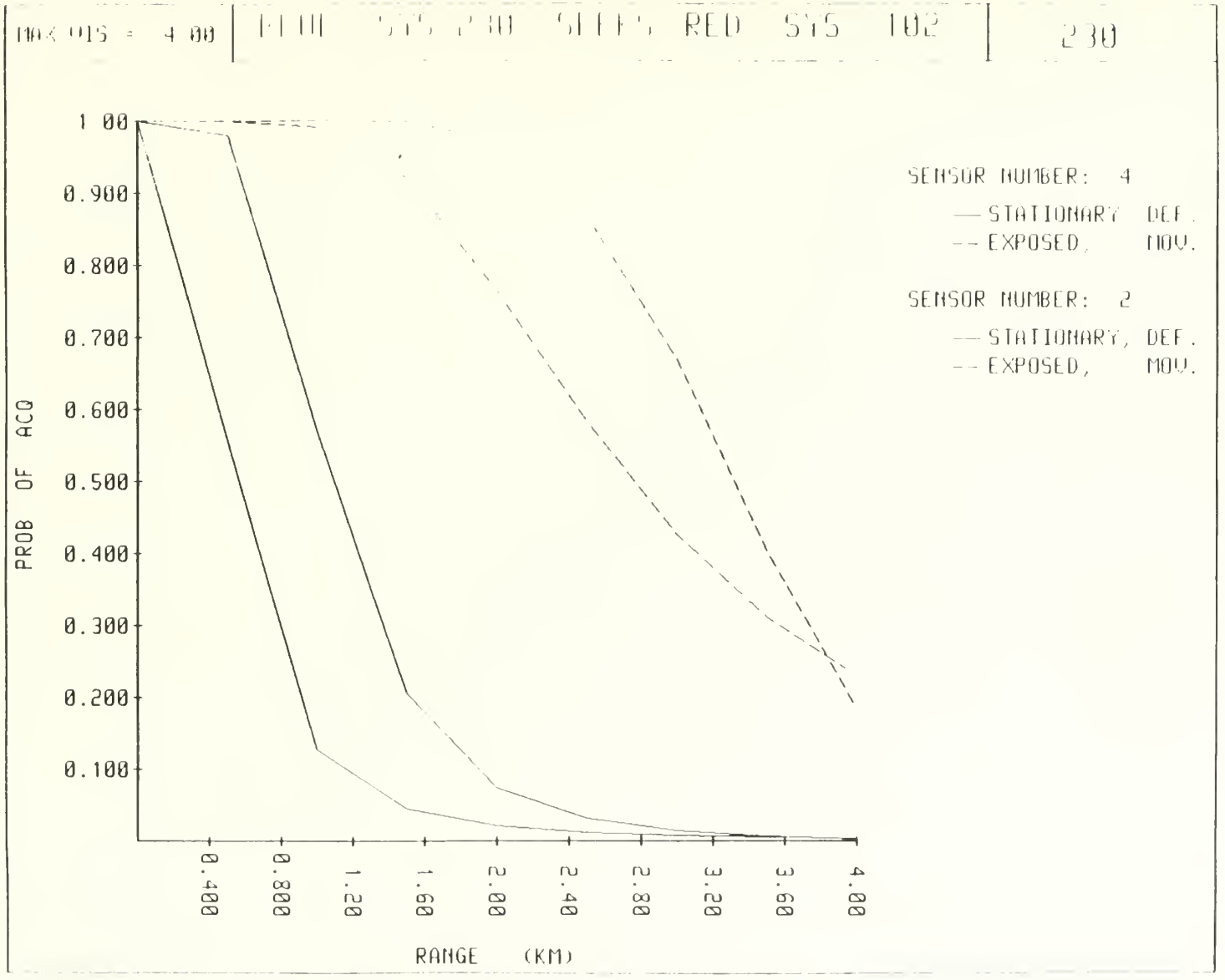

Figure 9. Blue TEISS Rifleman (230) seeks Red Rifleman (102)

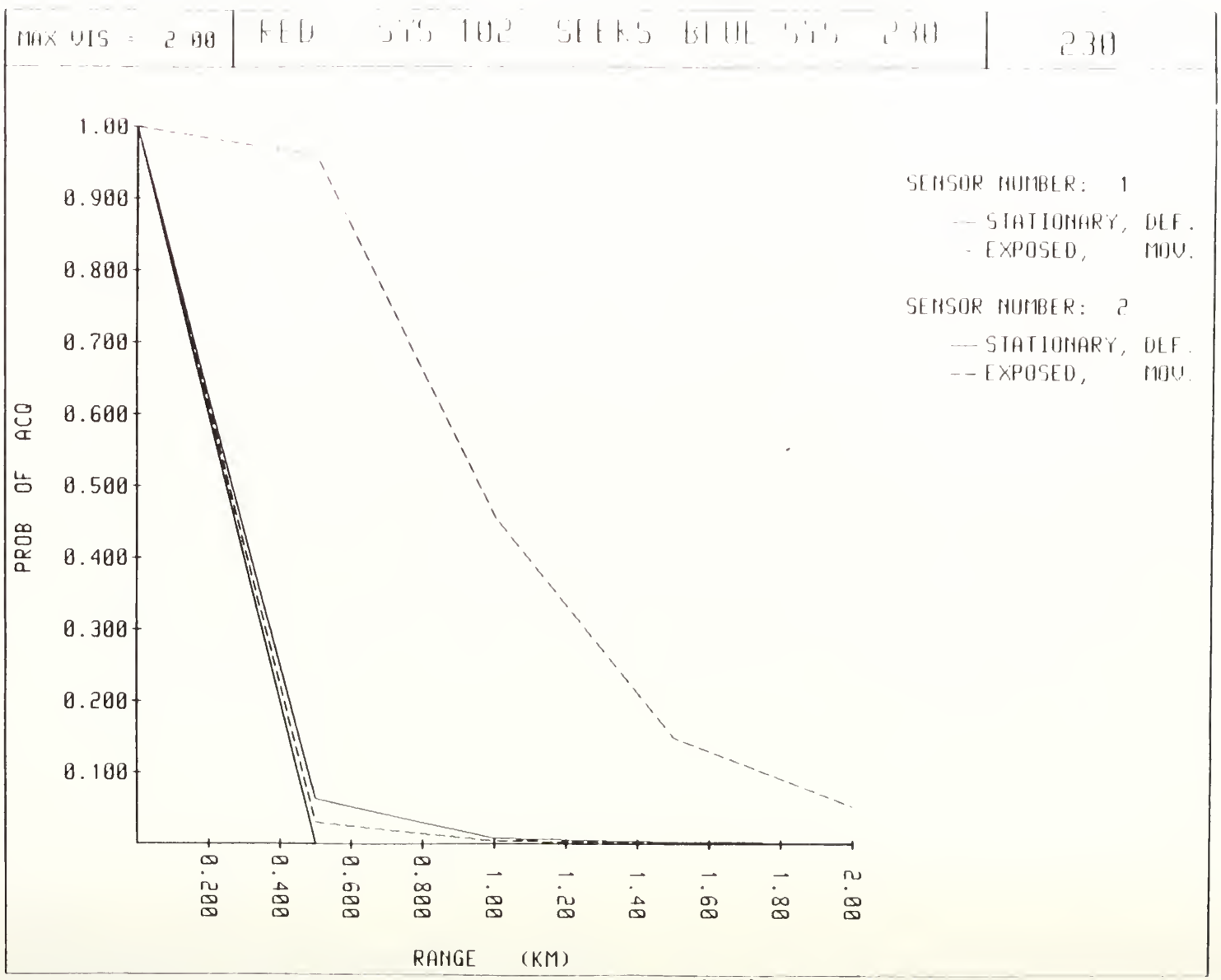

Figure 10. Red Rifleman (102) seeks Blue Rifleman (230)

APPENDIX D: AREA OF OPERATIONS USED IN STUDY

Figure 11 is a copy of the Hoenfehls training area used for this study. As mentioned in Chapter II, the Blue forces consisted of a standard nine man light infantry squad supplemented with a two man machine gun team in the offense. The Red forces included a standard twenty one man dismounted infantry platoon during both the offense and defense. The Blue icons in Figure 11 show where the Blue forces initially start while in the offense. The Red forces who are in the defense appears on a separate screen and is located on the hilltop around the vicinity of 9652.

When in the defense, the Blue forces were located around the hilltop in the vicinity of 955540. Two Red squads deployed from the south along the west side of the ridgeline and waited in the vicinity of 953533 while a third squad employed cover and concealment to envelope the Blue forces from the northwest. When using the eleven man Baseline Blue forces in the defense, the entire Red force was attrited without any Blue losses. Thus, in order to stress the limits of TEISS, the number of Blue forces in the defense was lowered to a five man team.

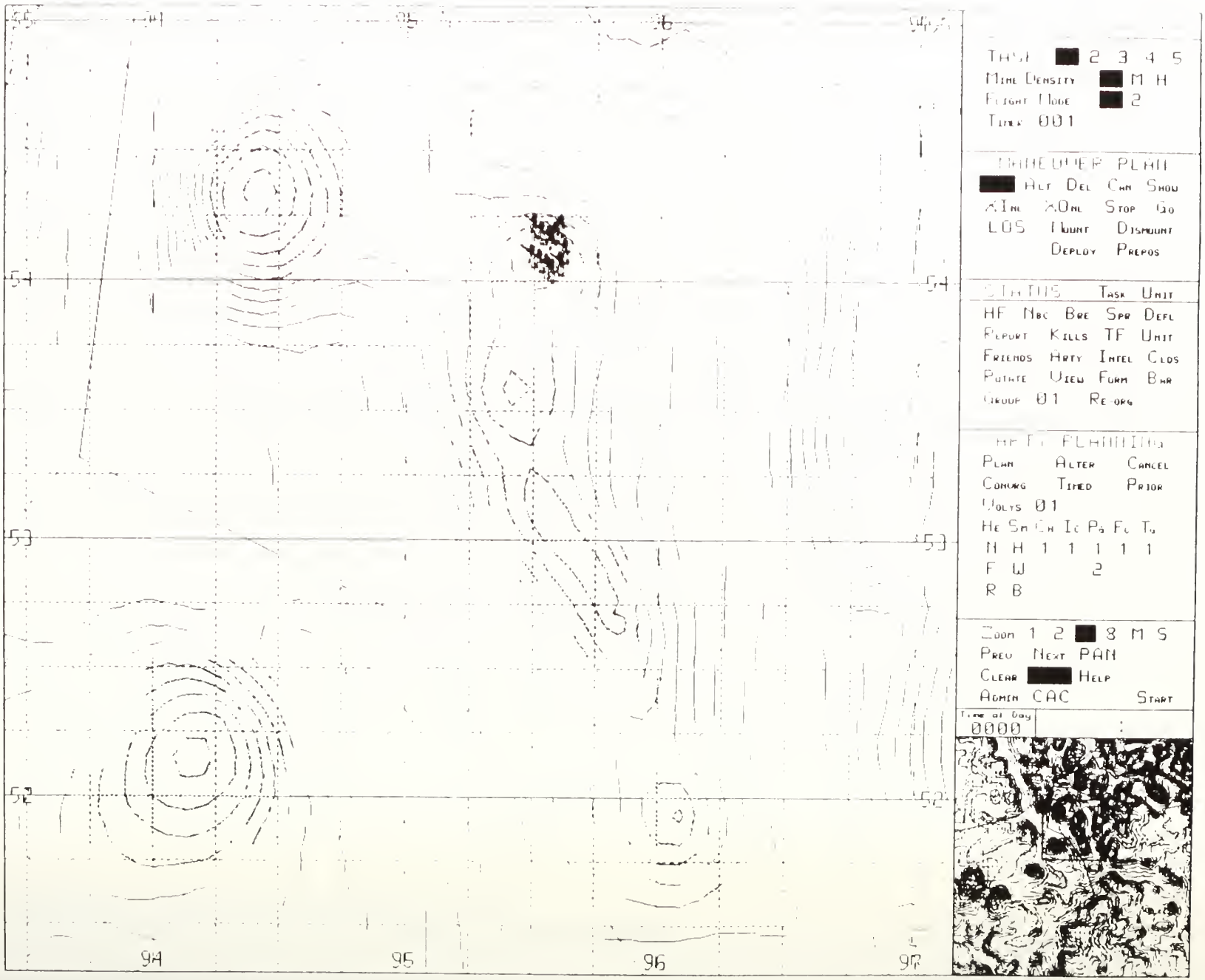

Figure 11. Map of the Area of Operations

APPENDIX E:

ALIAS TABLE AND CODED DESIGN MATRIX TABLE WITH INTERACTIONS

The 1/8 fractional factorial design used is a design of resolution IV which allows the analyst to look at all main effects but the design does confound two way interactions with other two-factor interactions.

The design generators are as follows:

E = ABC F = BCD G = ACD

The defining relation is :

I = ABCE = BCDF = ACDG = ADEF = BDEG = ABFG = CEFG

The Alias Table (up to 3 way interactions):

A	BCE	BFG	CDG	DEF		
B	ACE	AFG	CDF	DEG		
C	ABE	ADG	BDF	EFG		
D	ACG	AEF	BCF	BEG		
E	ABC	ADF	BDG	CFG		
F	ABG	ADE	BCD	CEG		
G	ABF	ACD	BDE	CEF		
AB	CE	FG				
AC	BE	DG				
AD	CG	EF				
AE	BC	DF				
AF	BG	DE				
AG	BF	CD				
BD	CF	EG				
ABD	ACF	AEG	BCG	BEF	CDE	DFG

The coded fractional factorial design matrix with interactions is given in Table 21. Note that the values for the interactions is just the product of their individual terms.

TABLE 21 FRACTIONAL FACTORIAL DESIGN WITH INTERACTIONS

A	B	G	D	E	F	G	AB CE FG	AC BE DG	AD CG EF	AE BC DF	AF BG DE	AG BF CD	BD CF EG	ABD
-	+	+	+	+	+	+	-	-	+	-	-	-	-	+
+	+	+	+	-	+	+	+	-	+	-	+	-	+	-
-	+	+	+	+	+	+	-	+	-	+	-	-	-	+
+	-	-	-	-	-	+	+	-	+	-	+	-	+	-
-	+	+	+	+	+	+	-	-	-	-	-	-	-	+
+	+	+	+	-	+	+	+	-	+	-	+	-	+	-
-	+	+	+	+	+	+	-	+	-	-	-	-	-	+
+	+	+	+	-	+	+	+	-	+	-	+	-	+	-
-	+	+	+	+	+	+	-	+	-	+	-	+	-	+
+	-	+	+	-	+	+	+	-	+	-	+	-	+	-
-	+	+	+	+	+	+	-	+	-	+	-	-	-	+
+	+	+	+	-	+	+	+	-	+	-	+	-	+	-
+	+	+	+	-	+	+	+	-	+	-	+	-	+	-
+	-	+	+	-	-	+	-	+	+	-	-	+	-	-
-	+	+	+	-	+	-	-	-	-	+	-	+	+	-
+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

APPENDIX F: RESULTS FROM EACH TRIAL

Tables 22 and 23 show the results from each of the eighty trials along with the means and standard deviations for the sixteen design points. Columns A through G shows the factor settings. Y_1 through Y_5 are the five replications of each design point and shows the actual results obtained for both lethality and survivability. Recall that the measure of effectiveness for lethality is the number of Red kills / number of Blue shots fired. The measure of effectiveness for survivability is the number of Blue survivors / number of starting Blue forces.

TABLE 22 RESULTS FOR SURVIVABILITY

DET	FC	BP	ACQ	WT	SPD	SC	Y1	Y2	Y3	Y4	Y5	YAVG	∂
-	-	-	-	+	-	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0
+	-	+	-	+	-	+	0.0	0.0	0.0	0.0	0.0	0.0	0.0
+	+	-	+	+	+	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0
+	+	+	-	-	+	+	.909	.909	.727	.909	.818	.855	.081
-	-	+	-	+	-	+	.909	.727	.818	.818	.818	.818	.064
+	-	-	-	-	+	-	1.0	1.0	1.0	1.0	1.0	1.0	0.0
-	+	-	-	-	-	+	1.0	1.0	1.0	1.0	1.0	1.0	0.0
+	+	+	-	+	-	-	1.0	1.0	1.0	1.0	1.0	1.0	0.0
-	+	-	+	+	+	+	0.0	0.0	0.0	0.0	0.0	0.0	0.0
+	-	-	+	+	+	-	0.0	.800	0.0	.600	0.0	.240	.329
-	+	-	-	+	-	+	.364	.364	.636	.818	.636	.564	.197
+	+	-	+	-	-	-	.200	0.0	0.0	.600	.800	.200	.200
-	-	+	+	-	-	-	1.0	1.0	1.0	1.0	1.0	1.0	0.0
+	-	-	+	-	-	+	.800	.636	.800	.600	.727	.800	.119
-	+	+	+	-	+	-	1.0	1.0	1.0	1.0	1.0	1.0	0.0
+	+	+	+	+	+	+	1.0	.818	1.0	1.0	1.0	.964	.081

TABLE 23 RESULTS - LETHALITY

DET	FC	BP	ACQ	WT	SPD	SC	Y1	Y2	Y3	Y4	Y5	YAVG	$\hat{\sigma}$
-	-	-	-	-	-	-	.192	.389	.143	.107	.342	.235	.328
+	-	-	-	+	-	-	.333	0.0	0.0	0.0	.102	.100	.161
-	+	-	-	+	+	-	.375	.021	.548	.472	.410	.446	.067
+	+	-	+	+	+	+	.089	.098	.098	.061	.089	.085	.098
-	-	-	-	+	+	-	.086	.127	.153	.077	.071	.101	.536
+	-	-	-	-	+	-	.152	.119	.253	.147	.134	.161	.553
-	+	+	-	-	-	-	.356	.328	.309	.344	404	.342	.536
+	+	-	-	+	-	-	.568	.568	.553	.467	.100	.009	.079
-	-	-	+	-	+	-	0.0	.138	0.0	.138	0.0	.051	.070
+	-	-	+	+	+	-	.255	.121	.242	.119	.273	.007	.098
-	+	-	+	+	-	+	.396	.362	.404	.375	.356	.328	.021
+	+	-	+	-	-	-	.333	.536	.438	.420	.583	.462	.099
-	-	+	+	+	-	-	.112	.146	.250	.208	.210	.185	.055
+	-	+	+	-	-	-	.064	.077	.074	.061	.060	.067	.028
-	+	+	+	-	+	-	.350	.568	.553	.618	.420	.502	.112
+	+	+	+	+	+	+	.356	.412	.356	.404	.389	.383	.026

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